
Abstract The health burden and resultant economic burden of foodborne norovirus disease among school-age children in the U.S. is unknown, but believed to be significant. The economic burden encompasses not only direct medical costs associated with medical care but also indirect costs such as loss of work days and direct nonmedical costs. National passive surveillance data from norovirus outbreaks spanning 2009–2013 were used to identify cases, health outcomes, interventions, and healthcare resource utilization among the school-age population. The cost of supportive care was $2,483,379, outpatient healthcare was $57,672, hospitalization was $48,670, and emergency care was $38,336. The cost of providing supportive care (direct nonmedical costs) was relatively low. When indirect costs were factored in, however, the total cost of care escalated, which illustrates the high burden of loss of productivity. It is important to incorporate the indirect and direct nonmedical costs of disease to more accurately characterize the total economic burden of a disease.

Introduction

Economic Burden of Norovirus Disease

Characterization of the impact of norovirus disease among the school-age population should involve estimating its health burden, as well as its economic burden. Estimates of health burden in terms of mortality and morbidity provide important insight into disease risk and severity. The economic burden, on the other hand, provides insight into the healthcare resource utilization associated with the disease. Researchers conducting an economic burden study of a disease should also examine all potential costs.

Many studies report only direct medical costs (i.e., outpatient, inpatient, medications, diagnostic tests, etc.) while ignoring the direct nonmedical costs (i.e., transportation, over-the-counter medications) and indirect costs (i.e., lost productivity incurred by the caregivers) borne by the patient, caregivers, healthcare system, employers, and society at large. Economic burden estimation that factors in these costs and provides a more accurate assessment of the true burden of a disease can then help to identify and prioritize influential cost drivers, as well as offer greater insight into future cost trends.

Research evidence suggests that norovirus and 13 other foodborne pathogens account for 95% of all confirmed foodborne illnesses and associated hospitalizations. These 14 foodborne pathogens account for 98% of foodborne deaths in the U.S. (Batz, Hoffmann, & Morris, 2012). Given its high incidence and severity of symptoms such as vomiting and diarrhea, the health burden and resultant economic burden of norovirus disease were reported to be significant by previous studies (Debbink, Lindesmith, Donaldson, & Baric, 2012; Scallan et al., 2011). Norovirus-associated hospitalizations alone were estimated to cost $500 million per year in the U.S. (Batz, Hoffmann, & Morris, 2011). When the cost for lost average daily wages, that is, “lost labor market productivity,” were added to healthcare costs, the cost of norovirus gastroenteritis was estimated to be $2 billion (Batz et al., 2011).

In a simulation model, researchers examined the annual disease and economic burdens of norovirus in the absence of a vaccine. They estimated that 16.7 million norovirus cases result in 1.8 million outpatient visits, 69,000 hospitalizations, and 800 deaths in a year, at an annual cost of $5.5 billion in direct medical costs (Bartsch, Lopman, Hall, Parashar, & Lee, 2012). In a study conducted by Hall and coauthors (2013), incidence data from previous studies spanning 1979–2009 were analyzed in order to derive greater accuracy for estimates of acute gastroenteritis associated with norovirus. They estimated that there are 19–21 million cases of norovirus, 1.7–1.9 million outpatient visits, 400,000 emergency room visits, and 570–800 deaths in a year, at an annual healthcare cost of approximately $777 million (Hall et al., 2013).

Gastañaduy and coauthors (2013) used rates of emergency room and outpatient visits for gastroenteritis from July 2001–June 2009 to estimate the economic burden of norovirus in ambulatory settings. They extrapolated MarketScan rates to the U.S. population-
based claims, encounters, and the healthcare charges. The total healthcare charges for emergency room visits for children 5–17 years, based on an extrapolated annual estimate of 54,000 visits, was $18 million. The total healthcare charges for outpatient visits for children 5–17 years, based on an extrapolated annual estimate of 453,000 visits, was approximately $34 million (Gastañaduy, Hall, Curns, Parashar, & Lopman, 2013).

In another study examining the incidence of norovirus among children under 5 years during the years 2009–2010, researchers estimated that each year, norovirus resulted in 14,000 hospitalizations ($3,918 per hospitalization), 281,000 emergency care visits ($435 per visit), and 627,000 outpatient healthcare visits ($151 per visit) (Payne et al., 2013). The estimated cost of treatment was $273 million each year for children under 5 years of age. Lopman and coauthors (2011) analyzed and modeled the annual hospital discharges and estimated that there were 5,584 per 100,000 associated with norovirus discharges among children 5–17 years at a cost of $27 million (Lopman, Hall, Curns, & Parashar, 2011).

Batz and coauthors (2011) designed a study in order to derive more accurate attribution estimates and examined yearly variability of economic burden using outbreak data from 1999–2008. They found that on an annual basis, the mean number of norovirus illnesses for all ages was estimated to be 5,461,731 (range of 3,227,078–8,309,480), a mean of 14,663 hospitalizations (range of 8,097–23,323), and a mean of 149 deaths (range of 84–237) for norovirus disease (Batz et al., 2012). All of the previous published norovirus cost estimates were based on documented cases requiring medical treatment in healthcare settings.

To date, there is no estimate of the economic burden associated with norovirus disease in the school environment in the U.S. The school environment represents a closed setting and an optimal environment to facilitate the spread of norovirus disease to the community and beyond. The purpose of this study was to estimate the direct medical, nonmedical, and indirect costs of norovirus disease among school-age children enrolled in the U.S. (The World Bank, 2013). Previous studies have not captured and categorized costs in this way.

Norovirus outbreaks that occur in healthcare settings can be contained more rapidly and its spread limited, while it is difficult to contain those outbreaks that occur in closed settings where individual re-enter the community and perpetuate the spread of disease to susceptible individuals. A norovirus outbreak in a school setting can impact 50% or more of the total school population, which does not include transmission outside this closed environment (i.e., to family members) (Gomez, 2008).

One recent study compared the cost of norovirus outbreaks in closed environments with those that occur in the community and found that outbreaks in closed settings are more costly than those that occur in the community (Navas et al., 2015). This study estimated that the direct medical (i.e., hospitalization), direct nonmedical (i.e., travel for medical treatment), and indirect costs (i.e., work, school absenteeism) in a closed environment were $5,454.67 per outbreak, while the costs of a community outbreak were $3,829.60 per outbreak (Navas et al., 2015).

### Table 1

<table>
<thead>
<tr>
<th>Year</th>
<th>Estimation Method</th>
<th>Cases</th>
<th>Outpatient Healthcare</th>
<th>Emergency Care</th>
<th>Hospital Admissions/Discharges</th>
<th>Death</th>
<th>Total Cost</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979–2009</td>
<td>Attributable proportion (all age groups, U.S.)</td>
<td>19–21 million</td>
<td>1.7–1.9 million visits</td>
<td>400,000 visits</td>
<td>5,854 discharges per 100,000 admissions</td>
<td>570–800</td>
<td>$777 million</td>
<td>Hall et al., 2013</td>
</tr>
<tr>
<td>2001–2009</td>
<td>Estimated annual mean rates (children 5–17 years, U.S.)</td>
<td>627,000 visits</td>
<td>$95 million</td>
<td>14,000 admissions</td>
<td>$55 million</td>
<td>$273 million</td>
<td>Payne et al., 2013</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>Incidence estimates (all age groups, U.S.)</td>
<td>$500 million</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>Incidence estimates (all age groups, U.S.)</td>
<td>69,000 admissions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note.** Costs expressed as 2013 U.S. dollars.
Several studies have attempted to estimate the health and economic burdens of norovirus disease using various methodological approaches. The health outcomes—defined as the number of cases, outpatient visits, emergency room visits, plus hospitalizations and associated medical costs—vary widely, but are costly regardless of the methodology used to calculate total costs (Table 1).

**Methods**

**Data Sources and Analyses**

Passive surveillance data on norovirus disease outbreaks from 2009–2013 among school children in the U.S. obtained from the Centers for Disease Control and Prevention’s (CDC) National Outbreak Reporting System (NORS) were used to calculate the incidence (CDC, 2013). Norovirus health outcomes based on the laboratory confirmed and suspected norovirus cases were defined by severity of healthcare intervention (i.e., outpatient healthcare, emergency care, hospitalization, or death).

Healthcare resource utilization data obtained from the Healthcare Cost and Utilization Project (U.S. Department of Health and Human Services [HHS], 2012a, 2012b) were used to estimate medical costs. Unit costs for healthcare resource utilization were obtained using selected ICD-9 codes. The ICD-9 codes included 008.63, 008.8, 009.0, 009.1, 009.2, and 009.3, and were based on the definition for infectious gastroenteritis (Health Fusion, Inc., 2017). Direct medical costs included expenses associated with outpatient healthcare, emergency care, and hospitalization inclusive of other related expenses such as physician fees, laboratory tests, diagnostic tests, and medications. For this study, direct nonmedical costs included oral rehydration therapy, prescriptions, and over-the-counter medications. In addition, direct nonmedical costs included those costs associated with transportation and included travel costs to and from medical facilities (e.g., outpatient healthcare, emergency care, or hospitalization), whereas indirect costs were those costs associated with lost productivity or lost work time for caregivers as a result of caring for the child suffering with norovirus illness (Gold, Siegel, Russell, & Weinstein, 1996).

**Direct Medical Costs**

The direct medical costs for outpatient care were estimated by calculating healthcare resource utilization based on unit cost per visit. The direct medical costs for emergency care were estimated by calculating healthcare resource utilizations based on unit cost per visit, diagnostic tests, and medications (Blue Cross and Blue Shield Association, 2009; Gastañaduy et al., 2013; Payne et al., 2013). The direct medical costs for hospitalizations were estimated by calculating healthcare resource utilizations based on unit cost per stay, diagnostic tests, and medications based on a typical duration of stay of 2 days (HHS, 2012a, 2012b).

**Direct Nonmedical Costs**

The direct nonmedical costs were estimated by calculating the average expenses of travel and transportation to medical facilities in order to facilitate the recovery of the child. These costs include fuel consumed and amount of time it takes to travel to the destination. The average time it takes to commute to work is assumed to be 25 minutes (McKenzie, 2013, 2014). The transportation calculation includes the cost of fuel by the amount consumed, and the hourly wage of the caregiver by the number of hours the caregiver spends in transit to and from treatment facilities (American Automobile Association, 2017; Bouzón-Alejandro et al., 2011; U.S. Department of Energy, 2016). Other costs such as meals away from home, oral rehydration therapy, and over-the-counter medications were also included (Bartsch et al., 2012; Bouzón-Alejandro et al., 2011).

**Indirect Costs**

The results from published research studies indicate that, on average, a caregiver (time and cost of a caregiver taking off from work and away from routine activities) takes about 2–3 days to care for a sick child (National Institutes of Health, 2017). It is assumed that the time a caregiver takes to transport a sick child to medical facilities would otherwise be time spent in traveling to work. It is also assumed that the time a caregiver spent at the medical facility would be time otherwise spent at work. The indirect costs were estimated by calculating the average gross

### Table 2

**Direct Medical Cost Estimates**

<table>
<thead>
<tr>
<th>Healthcare Intervention</th>
<th>Unit Cost Mean (Range)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outpatient healthcare (per visit): Children 5–16 years</td>
<td>$175 ($160–$190)</td>
<td>Blue Cross and Blue Shield Association, 2009; Payne et al., 2013</td>
</tr>
<tr>
<td>Emergency care (per visit): Children 5–16 years</td>
<td>$572 ($510–$635)</td>
<td>Blue Cross and Blue Shield Association, 2009; Gastañaduy, Hall, Curns, Parashar, &amp; Lopman, 2013; Payne et al., 2013</td>
</tr>
<tr>
<td>Emergency care (per visit): Children 5–17 years</td>
<td>$333 ($240–$580)</td>
<td></td>
</tr>
<tr>
<td>Hospitalization (per 2 days)</td>
<td>$3,464 ($2,877–$4,062)</td>
<td>U.S. Department of Health and Human Services, 2012a, 2012b</td>
</tr>
</tbody>
</table>

*Note. Costs expressed as 2013 U.S. dollars.*
weekly wages by the number of lost work days or hours due to outpatient visits, emergency care, or hospitalizations for a sick child (Constenla et al., 2008; U.S. Bureau of Labor Statistics, 2013).

In order to estimate the economic burden of norovirus disease, we first calculated the illnesses and incidence proportion by health intervention among the school-age population. We then calculated costs for each type of health intervention and categorized costs as direct medical, direct nonmedical, or indirect costs. Finally, we calculated the total costs, which were derived by multiplying the number of cases by the unit cost for each type of health intervention.

Results

Direct Medical, Direct Nonmedical, and Indirect Costs

Based on the estimation of direct medical costs for outpatient care, emergency care, and hospitalizations, total direct medical costs for an episode of norovirus infection are largely due to hospitalizations, followed by emergency care, outpatient care, and finally supportive care (Table 2). Direct nonmedical cost estimates for travel and transportation to medical facilities, as well as meals away from home, oral rehydration therapy, and over-the-counter medications were negligible, but when factored in with indirect costs, the economic burden for all outcomes were much higher (Table 3).

Indirect cost estimates for lost productivity for a caregiver varied depending on the health intervention. The cost for supportive care is relatively inexpensive when considering treating the symptoms of the infection with oral rehydration fluid and over-the-counter medications. When lost productivity is factored into the total cost, however, indirect costs accounted for a sizable proportion of the expenditures and were second to and slightly less than direct medical costs (Table 4).

Based on the NORS surveillance data number of cases for each health intervention, the estimated cost of supportive care was $2,483,379 (94.5%), outpatient healthcare was $57,699 (2.2%), hospitalization was $48,674 (1.9%), and emergency care was $38,348 (1.5%) (Table 5).

Discussion

The present study examined the economic burden of norovirus disease among school-age children from 2009–2013, estimating direct medical, direct nonmedical, and indirect costs. The results align with findings from previous studies regarding costs for supportive care, outpatient healthcare, emergency care, and hospitalization.

Previous studies have illustrated that norovirus disease results in significant health expenditures in terms of direct medical, direct nonmedical, and indirect costs associated with the disease. The economic burden for norovirus is considerable, with costs for supportive care at $255.4 million, healthcare provider visits at $283.7 million, and hospitalization at $285.9 million (Batz et al., 2012; CDC, 2013; Debbink et al., 2012; Mast, DeMuro-Mercon, Kelly, Floyd, & Walter, 2009). Among the health interventions for norovirus illness, supportive care represented the lowest cost of all health outcomes, while outpatient healthcare, emergency care, and hospitalization resulted in progressively higher costs for medical treatment, respectively.

Direct Medical, Direct Nonmedical, and Indirect Costs

A majority of the norovirus cases among the school-age population required supportive care, followed by outpatient healthcare, emergency care, and hospitalization. The cost for supportive care is relatively inexpensive when considering treating the symptoms of the infection with oral rehydration fluid and over-the-counter medications. The total direct medical costs for an episode of norovirus infection are largely due to hospitalizations, followed by emergency care, outpatient healthcare, and finally supportive care.
direct nonmedical and indirect costs were factored in, however, the economic burden for all health outcomes was much higher. As other study findings indicate, indirect costs typically account for a sizable proportion of all costs: mainly due to caregiver loss of productivity while caring for a child afflicted with norovirus infection.

In the present study, indirect costs accounted for a sizable proportion of the expenditures for all categories of costs and were only second to and slightly less than direct medical costs (Belliot, Lopman, Ambert-Balay & Pothier, 2014; Navas et al., 2015; Payne et al., 2013). Lower norovirus health outcome estimates were obtained in the present study compared with previous cited research findings related to norovirus disease in children 5–17 years of age. One reason for the difference is that previous studies obtained estimates from confirmed norovirus hospitalizations, emergency care, and outpatient healthcare in all types of settings; whereas the present study obtained estimates from surveillance data.

The NORS passive surveillance system contains data on outbreaks among school-age children and data are often incomplete; the NORS data spanning 2009–2013 were obtained from outbreaks that occurred in 34 states rather than all 50 states. Furthermore, states differ in reporting procedures, and it has been established that there is an underreporting factor of 1.7 in the early phase of norovirus outbreaks (Bernard, Werber, & Höhle, 2014). Although use of surveillance data has limitations, which underestimates the burden of disease and consequently may not be generalizable to the school-age population at large, the results provide insights into the large proportion of cases and high expenses for cases that require supportive care.

Moreover, there are limitations to using cost data from various study findings identified in a literature review to estimate the economic burden of norovirus because there are methodological differences across studies. The present study did not measure all pos-

**TABLE 4**

Indirect Cost Estimates

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>Quantity</th>
<th>Average Weekly Earnings</th>
<th>Unit Cost Mean</th>
<th>Cost/Episode</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supportive care, outpatient healthcare, and emergency care: Caregiver lost productivity</td>
<td>2 days (≈ 16 hr)</td>
<td>$691 (women) $768 (men)</td>
<td>$17/hr $19/hr</td>
<td>$276 $308 (mean = $292)</td>
<td>Constenla et al., 2008; Lorgelly et al., 2008; Mast, DeMuro-Mercon, Kelly, Floyd, &amp; Walter, 2009; U.S. Bureau of Labor Statistics, 2013</td>
</tr>
<tr>
<td>Hospitalization: Caregiver lost productivity during hospitalization</td>
<td>2 days (≈ 16 hr)</td>
<td>$691 (women) $768 (men)</td>
<td>$17/hr $19/hr</td>
<td>$276 $308</td>
<td>Constenla et al., 2008; Lorgelly et al., 2008; Mast et al., 2009; U.S. Bureau of Labor Statistics, 2013</td>
</tr>
<tr>
<td>Caregiver lost productivity following hospitalization</td>
<td>2 days (≈ 16 hr)</td>
<td>$691 (women) $768 (men)</td>
<td>$17/hr $19/hr</td>
<td>$276 $308 (mean = $292)</td>
<td></td>
</tr>
</tbody>
</table>

*Note. Costs expressed as 2013 U.S. dollars.*

**TABLE 5**

Cost of Norovirus Infection by Health Outcomes (2009–2013)

<table>
<thead>
<tr>
<th>Healthcare Intervention</th>
<th>Cost Items</th>
<th>Cost/Case Mean</th>
<th>Total Cases ((n = 4,114))</th>
<th>Total Cost for Health Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supportive care</td>
<td>Oral rehydration therapy, over-the-counter medications, lost productivity</td>
<td>$621</td>
<td>3,999</td>
<td>$2,483,379</td>
</tr>
<tr>
<td>Outpatient healthcare</td>
<td>Visit, transportation, fuel, lost productivity</td>
<td>$801</td>
<td>72</td>
<td>$57,672</td>
</tr>
<tr>
<td>Emergency care</td>
<td>Visit, transportation, fuel, lost productivity</td>
<td>$1,198</td>
<td>32</td>
<td>$38,336</td>
</tr>
<tr>
<td>Hospitalization</td>
<td>Caregiver, transportation, fuel, meals, lost productivity</td>
<td>$4,867</td>
<td>10</td>
<td>$48,670</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td>$2,628,057</td>
</tr>
</tbody>
</table>

*Note. Costs expressed as 2013 U.S. dollars.*

**Strengths and Limitations**

This study is the first attempt to estimate the total economic burden of norovirus disease using surveillance data, which was derived from norovirus outbreaks among the school-age population—that is, data not derived solely from a healthcare source. As previous studies have indicated, only a small proportion of those individuals ill with norovirus seek the care of a healthcare provider or undergo laboratory testing to confirm norovirus. Thus, the majority of the supportive care cases go undetected and unreported (Bernard, et al., 2014).
sible costs associated with norovirus disease. Other costs associated with norovirus include costs of staff and student absenteeism, school closures, environmental decontamination, and sanitation.

The results of a simulation study on the cost of a norovirus case in a healthcare facility were estimated to be $6,237 plus or minus $3,211 (Virox Technologies, Inc., 2011). Clorox bleach estimated that student absenteeism costs on average $125 per student per episode of norovirus infection (Clorox, 2017). Intangible costs such as pain and suffering were not included in the study.

Conclusion
The present study illustrates that the economic burden of norovirus disease is substantial and encompasses more than the cost to treat the disease. Both direct medical and direct nonmedical costs are high; indirect costs, however, are comparatively higher, especially when considering lost productivity for a caregiver. Indirect costs, which were almost as much as direct medical costs, therefore contribute a considerable and sizable portion of all costs for an episode of disease. The inclusion of other costs, such as those involved in caring for a child, are also important to accurately estimate the total cost of the disease. In addition, in terms of costs, it is clear that more than 50% of the economic burden comes from the direct nonmedical and indirect costs. These findings suggest that the economic burden costs found in the literature, based only on direct medical costs, are underestimated by 50%.

Vaccination could reduce the incidence of norovirus infection and consequently reduce and lessen the economic burden of disease, as witnessed by the introduction of rotavirus vaccination among children (Laidman, 2014). Future research efforts on the economic impact of norovirus should incorporate costs of school closures in terms of student and staff absenteeism. In addition, costs should also include the cost of environmental decontamination and sanitation. Norovirus remains a nonreportable disease except for those in the military service (Armed Forces Health Surveillance Branch, 2009). Designating norovirus a reportable disease should be considered by policy makers.

Corresponding Author: Margaret M. Venuto, Management, Policy, and Community Health, University of Texas School of Public Health, San Antonio Regional Campus, 1009 Magoffthy Park Lane, Annapolis, MD 21409. E-mail: margaretvenuto@gmail.com.

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Did You Know?

NEHA has recently launched a new credential! The Certified Foodborne Outbreak Investigator (CFOI) credential is for individuals who utilize environmental health principles and food safety knowledge in collaboration with outbreak response partners to assess foodborne illness risks. The CFOI will prepare individuals to also perform environmental assessments, identify contributing factors and antecedents, and implement control measures to prevent the spread of foodborne illness and protect the public. Learn more at www.neha.org/credentials.